

2014 Regulatory Information Conference

Degradation of Boral in Spent Fuel Pool at Taiwan's BWR NPPs

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March 13, 2014

Outline

- **Background Information**
- **Boral Coupon Surveillance Program and Acceptance Criteria**
- **Experience of Chinshan NPP**
- **Experience of Kuosheng NPP**
- **AEC's regulatory activities**
- **Corrective Actions Taken by TPC**
- **Conclusion and Remark**

Background Information 1/2



GE BWR-4 1840 MWt \times 2
Commercial Unit1 12-1978
Unit2 07-1979

Chinshan 1&2

Kuosheng 1&2

Lungmen 1&2

Taipei



GE BWR-6 2943 MWt \times 2
Commercial Unit1 12-1981
Unit2 03-1983



Westinghouse PWR
2822 MWt \times 2
Commercial: Unit1 07-1984
Unit2 05-1985

Maanshan 1&2



GE ABWR 3926 MWt \times 2
Under Construction

Background Information 2/2

Plant	Time of Re-rack	SFP Capacity per Unit	Loaded Unit 1 Unit 2	Rack Vendor	Boral Vendor	Neutron-Absorbing Materials
Chinshan	1986 1998	3083	2982 2856	Holtec ¹	AAR	Boral
Kuosheng	1991 2003	4398	4180 4068	Holtec ENSA ²	AAR AAR Brooks & Perkins, Michigan ²	Boral

Data up to Feb. 2014

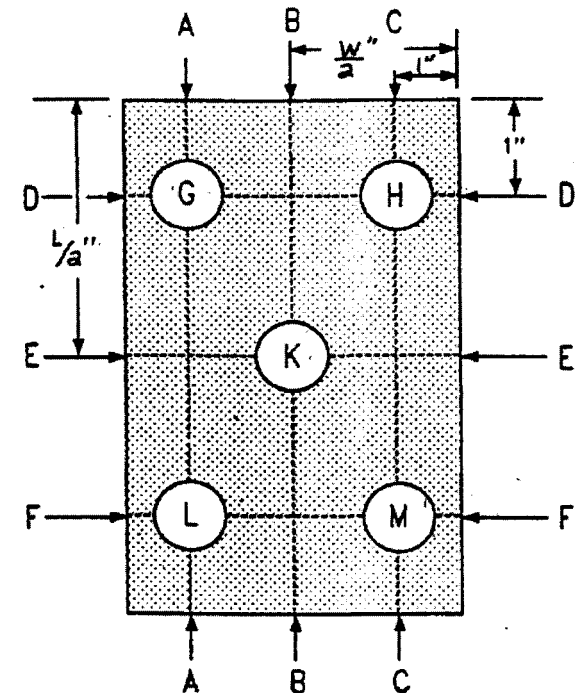
1. CS SFPs contain Holtec racks only.
2. KS SFPs contain Holtec racks and ENSA racks.

Boral Coupon Surveillance Program and Acceptance Criteria

- The test is performed per plant's procedure and at the onsite radiochemistry laboratory
- Test frequency, Test items, Test method and Acceptance criteria for degradation/deformation of Boral surveillance are suggested by manufacturer.

Boral Coupon Surveillance Program and Acceptance Criteria (cont.)

- For CS:
 - Wet chemistry measurement of B-10 content, Thickness measurement(5 points), Visual inspection
 - Test frequency : per manufacturer's recommendation
 - Acceptance criteria
 - The B-10 contents shall be not less than the minimum allowed B-10 loading (0.0167 g/cm²).
 - An increase in the thickness at any chosen point should not exceed 8% of the initial thickness.



Boral Coupon Surveillance Program and Acceptance Criteria (cont.)

■ For KS/Holtec:

- Wet chemistry measurement of B-10 content, Thickness measurement(5 points), Visual inspection
- Test frequency : per manufacturer's recommendation
- Acceptance criteria
 - The B-10 contents shall be not less than the minimum allowed B-10 loading (0.011g/cm^2).
 - Thickness change at any chosen point should not exceed 1% of the initial thickness.
 - Weight change of the coupon should not exceed 1% of its original weight.

Boral Coupon Surveillance Program and Acceptance Criteria (cont.)

- For KS/ENSA:
 - Weight chemistry measurement of B-10 content, Thickness measurement(5 points), Visual inspection
 - Test frequency : per manufacturer's recommendation
 - Acceptance criteria
 - The B-10 contents shall be not less than the minimum allowed B-10 loading (0.02g/cm²).
 - Thickness change at any chosen point should not exceed 8% of the initial thickness.

Experience of Chinshan NPP

- Re-racking of spent fuel pool (SFP) of both units were done by Holtec in 1986 and 1998.
- In each SFP, there were 10 coupons mounted on the “coupon tree”
 - Are positioned axially within the central 8 feet of the fuel zone
 - The “coupon tree” is surrounded by freshly discharged fuel assemblies at each of the first five refueling outages following installation of the racks. From the fifth cycle on, the fuel assemblies surrounding the “coupon tree” remain in place for the remaining lifetime of the racks.

Experience of Chinshan NPP

- One coupon is then taken out each time for testing according to the schedule listed in the test procedure
- Up to 2013, totally 5 boral test coupons of each unit have been examined.
 - The unit 1 coupons showed blisters near the edge of the coupons was first discovered in Feb. 2007 (~8 yrs after installation)
 - The unit 2 coupons with blisters was first discovered in Feb. 2011. (~12 yrs after installation)
- Test results show that both meet the acceptance criteria .

Experience of Chinshan NPP (cont.)

- Considering test result of CS in 2007 and NRC IN 2009-26 , additional visual inspection was first conducted during the refueling outage of Chinshan unit 1 in April 2010.
 - **It was noticed that all of the six coupons remained in the pool were with blisters.**
- Surveillance conducted in Chinshan Unit 1 in Oct. 2011 showed that the B-10 contents(0.0218 g/cm^2) was within the acceptance criteria(0.0167 g/cm^2), but one point thickness change $> 8\%$.
- In March 2011, a visual inspection was conducted during the refueling outage of Chinshan unit 2.
 - All of the five coupons remained in the pool were also with blisters

Experience of Chinshan NPP (cont.)

- Evaluation of unit 2 March 2011 visual inspection result
 - Boral in rack are with stainless steel sheath, it would provide geometrical constraint on the degree of swelling.
 - B-10 contents of boral coupon is within the acceptance criteria, it suggests that boral in rack should be with no boron loss.

- A visual inspection was conducted during the following refueling outage of Chinshan unit 1&2 after March 2011.
 - 2 boral coupon show one more blister and blister of 1 boral coupon became larger.
 - The other 8 coupons reveal no change.

Experience of Kuosheng NPP

- First re-racking which covers the major part of spent fuel pool (SFP) was done by Holtec in 1991.
- Second re-racking which covers the remaining part of SFP was done by Spanish company ENSA in 2003.
- There are 4 boron coupon trees in KS unit 1(2 Holtec/2 ENSA;K1-4) and 2 coupon trees in KS unit 2(ENSA;K5-6). Each tree has 8 coupons mounted on it and are positioned axially .

Experience of Kuosheng NPP (cont.)

■ 2 Categories of boron coupon

□ For Long Term Surveillance

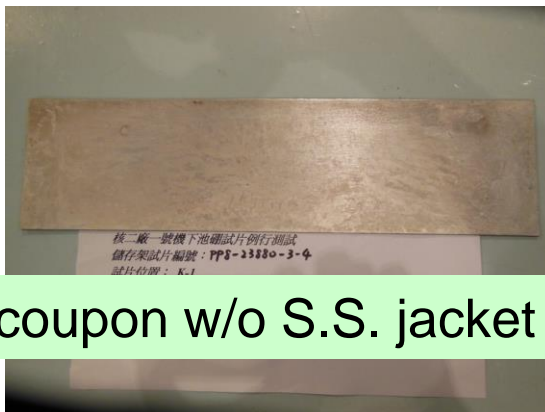
- **K-1(Holtec), K-3 and K-5(ENSA) “coupon tree”**
- Surrounded by freshly discharged fuel assemblies after the installation and remain in place for the remaining lifetime of the racks.
- A coupon test would be conducted every 5 years.

□ For Accelerated Surveillance

- **K-2(Holtec), K-4 and K-6(ENSA) “coupon tree”**
- Surrounded by freshly discharged fuel assemblies at each refueling outages.
- Every refueling outage a coupon test will be conducted. If it is within the acceptance criteria, the test interval can be extended to two refueling outages or more.

Experience of Kuosheng NPP

- Unlike the coupons of Chinshan, the Holtec Boral coupons at Kuosheng are jacketed in stainless steel.
- The non-jacketed coupons of the other manufacturer, ENSA, at Kuosheng had shown noticeable blisters, which is similar to Chinshan's operating experience



coupon w/o S.S. jacket



Boral with S.S. jacket

Experience of Kuosheng NPP (cont.)

- Surveillance results of coupon trees K-1/ K-3/ K-5
 - K-1(1997/2002/2008/2012) : 4 coupons have been examined, no blister
 - K-3(2010) : 1 coupon has been examined, no blister
 - K-5(2010) : 1 coupon has been examined, one blister with diameter around 1.5cm, thickness of the blister about 0.1cm
- Surveillance results of coupon trees K-2/K-4/K-6 :
 - K-2(2012) : 8 coupon has been examined, no blister
 - K-4(2011) : 3 coupon has been examined, 2 coupon with two blister (diameter ~1.3cm/ thickness ~ 0.1cm) ✕ first discovered in 2008
 - K-6(2011) : 3 coupon has been examined, 1 coupon with two blisters (diameter ~1.3cm/ thickness~ 0.1cm; diameter ~ 1cm / thickness ~ 0.048cm) ✕ first discovered in 2011

Experience of Kuosheng NPP (cont.)

- Up to 2013/12/31, totally 20 boral test coupons have been examined. Recently examined coupons showed blisters near the edge of the coupons.
- The Holtec Boral coupons at Kuosheng do not show any blister or bulge. It is quite possible that no blister could form in the jacketed coupon.

Experience of Kuosheng NPP (cont.)

- A visual inspection of Kuosheng unit 1 remaining K2/K4 was conducted in 2014.
 - K2(Holtec):no blister
 - K4(ENSA):blisters of remaining 5 coupons are almost as first discovered in 2010
 - The diameter of one blister grows from ~1.5cm to ~3cm, while the others remain unchanged.

AEC's regulatory activities

- Requested TPC to report CS and KS experience in using Boral through RAI.
- Requested TPC to inform Holtec about the results of Boral surveillance and visual inspection.
- Requested TPC to clarify potential safety impact, degradation mechanisms and study the possibility of in-situ and coupon neutron attenuation testing.
- Follow up action items to watch the surveillance activity and aging management program of Chinshan and Kuosheng.

Corrective Actions Taken by TPC

- Perform a justification that the effect of the blister was minor to criticality since no boron loss was found till now.
- Perform a friction test by using DUMMY bundle to verify the clearance between racks and fuel bundles to secure a practical fuel insertion activity to the racks.
- Holtec proclaimed that the blister was caused by hydrogen which generated from aluminum reacted with water in Chinshan. TPC considers that it's a likely cause of the blister in Chinshan and Kuosheng.
- Perform SFP water sampling weekly (boron/Al concentration, PH, conductivity)

Corrective Actions Taken by TPC

- TPC originally plans to establish a research project to further study the degradation mechanisms. But the project is suspended due to change of license renewal policy in Taiwan.
- TPC claimed that recent monitoring results show that the blistering phenomenon seems to be stabilized.
- A preliminary new action plan is proposed
 - If the test results shows that it does not meet the acceptance criteria or significant geometric degradation founded on boral coupon, TPC will conduct in-situ neutron attenuation test or add boral plate into rack.

Conclusion and Remarks

- The test results meet the acceptance criteria so far.
- Though no evidence shows a gradual degradation tendency, there are still some aspects need to study, e.g. degradation mechanism, effectiveness of surveillance monitoring programs.
- Information exchange among international nuclear community is important, especially in material degradation and aging issues .

Thank You for Your Attention